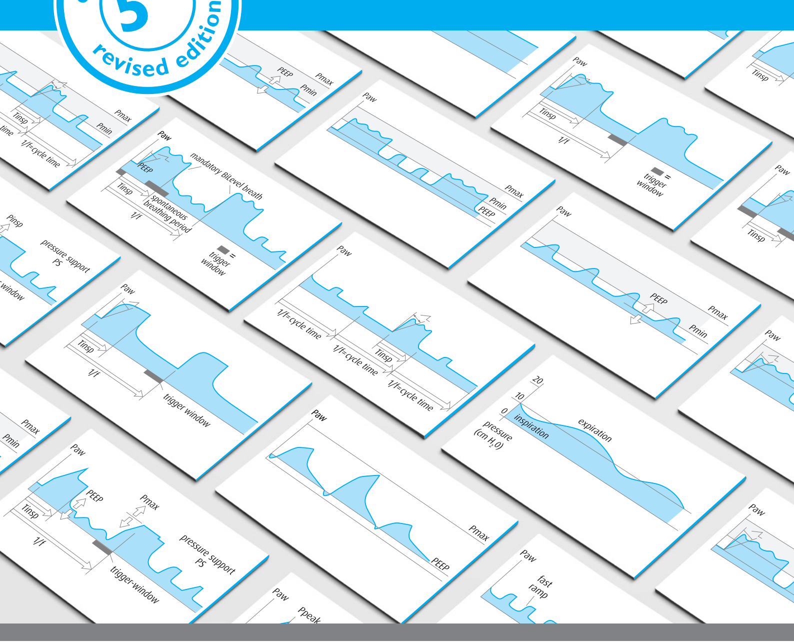
Peter Kremeier, Christian Woll

expanded and 5th revised edition



Understanding and comparing modes of ventilation

The Kronberg List of Ventilation Modes

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Preface

Numerous attempts to create a uniform classification system for ventilation modes have been unsuccessful. In many cases, they were more technical in design and were therefore perceived as unsuitable in everyday clinical practice. The publication of ISO standard 19223:2019 has now opened a new chapter on the way to a uniform nomenclature for ventilation modes. It is not yet foreseeable when ISO 19223 will become binding.

Some professional groups have questioned the suitability of the first standard version. For example, the classification of ventilation modes does not differentiate between proportional pressure support with or without a non-invasive method for measuring resistance or compliance (PPS or PAPS) and control with neurally adjusted ventilatory assist (NAVA). From a clinical perspective, the goal of drawing clear distinctions between the various modes has only been achieved in part. Accordingly, it is still unclear how to tell the different modes apart. Previous classification systems based on simple allocation to the categories "spontaneous", "pressure controlled" or "volume controlled” fail to include modern ventilation modes such as dynamic BiLevel, and closed-loop control modes such as IntelliVent ASV. Such an approach is therefore of little help for users when it comes to classifying clinical suitability. In an endeavour to provide our readers with a meaningful system of classification, we have settled on the following categories:

Volume-controlled ventilation modes

In volume-controlled ventilation, the pre-set tidal volume is applied regardless of airway resistance or lung compliance. Ventilation pressures depend on the current resistance and compliance.

Pressure-controlled ventilation modes

In pressure-controlled ventilation, the inspiratory pressure (Pinsp) is kept constant. The applied tidal volume depends on compliance.

Spontaneous ventilation modes

In patients unable to sustain unassisted breathing, spontaneous ventilation modes can support spontaneous breathing by keeping the alveoli open, or by reducing the patient's increased work of breathing.

Hybrid ventilation modes

As a further development of pressure-control ventilation, hybrid ventilation modes combine the known advantages of pressure-controlled ventilation forms with those of volume-constant ventilation. The users define a safe window with the settings parameters, in which the pressure levels can automatically adjust to the respective changes in the patient's lung.

Closed-loop ventilation modes

The term 'closed loop' refers to a group of ventilation modes which use complex algorithms or different input variables. These allow ventilatory support to adjust automatically in line with the patient's needs.

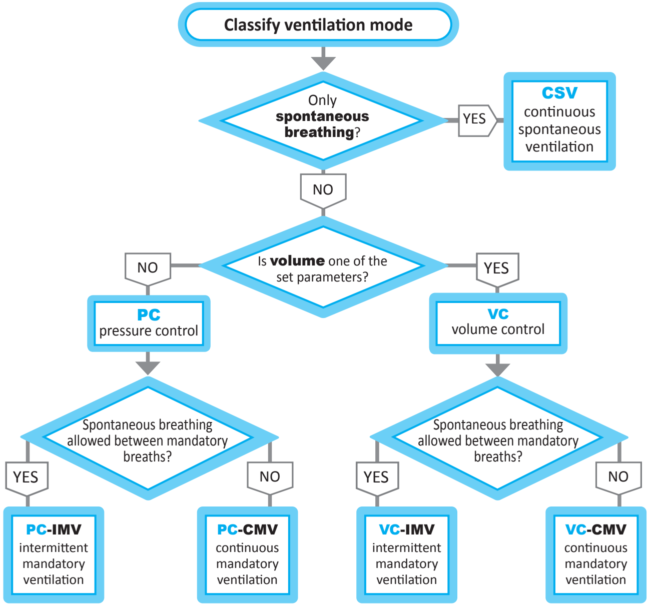
We are of course aware that one commonly finds small differences in the specifications of even similar modes of ventilation. Ventilation modes can also be modified with parameter settings (e.g., PSV with pressure support set to 0 = CPAP). However, these details have been carefully weighed, evaluated and allocated to the corresponding categories in the interest of comparability.

Due to the increasing relevance of outpatient ventilation devices in clinical use, the corresponding devices were also included in the comparison tables.

We would like to thank the RespiCode Trainings- und Simulationszentrum, Karlsruhe, Tobias Becher (UKSH Kiel) and Löwenstein Medical for their professional support.

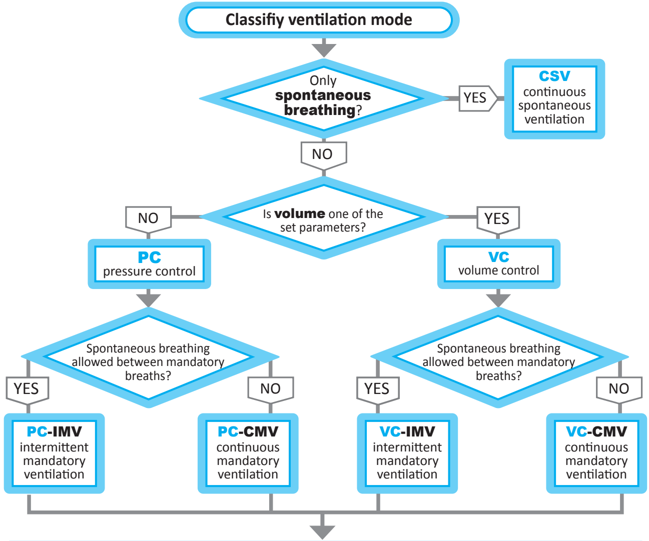
Karlsruhe, August 2020
Peter Kremeier, Christian Woll

Chatburn 2007


Classify ventilation mode
Only **spontaneous breathing**?
YES
CSV continuous spontaneous ventilation
NO
Is **volume** one of the set parameters?
NO
YES
PC pressure control
VC volume control
Spontaneous breathing allowed between mandatory breaths?
YES
NO
Spontaneous breathing allowed between mandatory breaths?
YES
NO
PC-IMV intermittent mandatory ventilation
PC-CMV continuous mandatory ventilation
VC-IMV intermittent mandatory ventilation
VC-CMV continuous mandatory ventilation

Chatburn, Robert L. 2007. "Classification of Ventilator Modes: Update and Proposal for Implementation." Respiratory Care 52 (3): 301 LP-323. http://rc.rcjournal.com/content/52/3/301.abstract.

Chatburn 2014

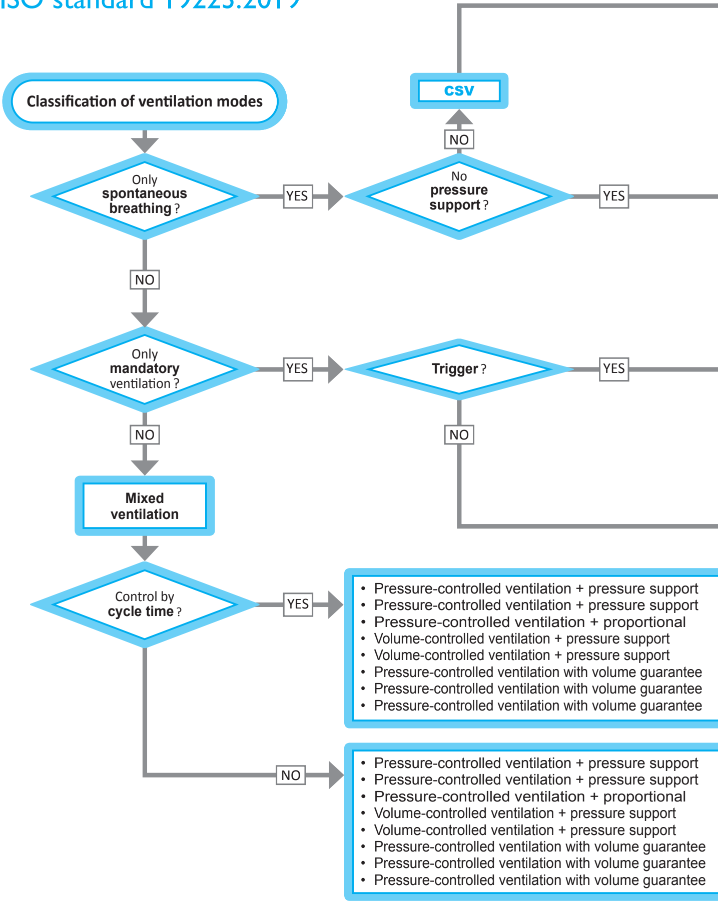

Classifiy ventilation mode
Only **spontaneous breathing**?
YES
CSV continuous spontaneous ventilation
NO
Is **volume** one of the set parameters?
NO
YES
PC pressure control
VC volume control
Spontaneous breathing allowed between mandatory breaths?
Spontaneous breathing allowed between mandatory breaths?
YES
NO
YES
NO
PC-IMV intermittent mandatory ventilation
PC-CMV continuous mandatory ventilation
VC-IMV intermittent mandatory ventilation
VC-CMV continuous mandatory ventilation

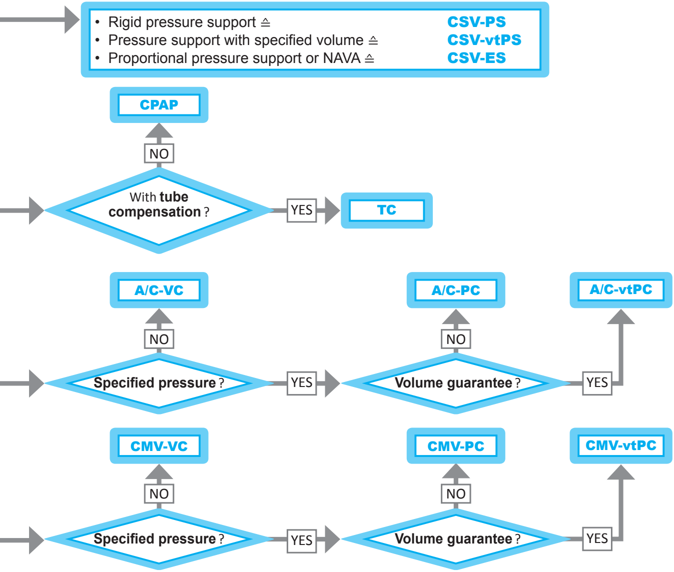
Supplement ventilation mode with the corresponding characteristic:

set-point	s	By adjusting the pressure ramp (pressure-controlled modes) or the flow pattern (volume-controlled modes)
dual	d	The ventilator switches automatically between volume control and pressure control.
servo	r	The pressure support is proportional to the inspiratory effort.
adaptive	a	In response to the changing patient status, the ventilator automatically adapts one target or more between two breaths.
biovariable	b	The ventilator adjusts the inspiratory pressure or the tidal volume randomly to mimic the variability observed during normal breathing.
optimal	o	The ventilator adapts the targets of the ventilatory pattern to achieve an overall performance characteristic (e.g., optimising the work of breathing).
intelligent	i	The control algorithms include artificial intelligence programs, such as rule-based expert systems or artificial neural networks.

Chatburn, Robert, Mohamad El Khatib, and Eduardo Mireles-Cabodevila. 2014. "A Taxonomy for Mechanical Ventilation: 10 Fundamental Maxims." Respiratory Care 59 (11): 1747–63. https://doi.org/10.4187/respcare.03057.

ISO standard 19223:2019


Classification of ventilation modes
Only spontaneous breathing ?
YES
No pressure support ?
NO
CSV
YES
NO
Only mandatory ventilation ?
YES
Trigger ?
YES
NO
NO
Mixed ventilation
Control by cycle time ?
YES
• Pressure-controlled ventilation + pressure support
• Pressure-controlled ventilation + pressure support
• Pressure-controlled ventilation + proportional
• Volume-controlled ventilation + pressure support
• Volume-controlled ventilation + pressure support
• Pressure-controlled ventilation with volume guarantee
• Pressure-controlled ventilation with volume guarantee
• Pressure-controlled ventilation with volume guarantee
NO
• Pressure-controlled ventilation + pressure support
• Pressure-controlled ventilation + pressure support
• Pressure-controlled ventilation + proportional
• Volume-controlled ventilation + pressure support
• Volume-controlled ventilation + pressure support
• Pressure-controlled ventilation with volume guarantee
• Pressure-controlled ventilation with volume guarantee
• Pressure-controlled ventilation with volume guarantee

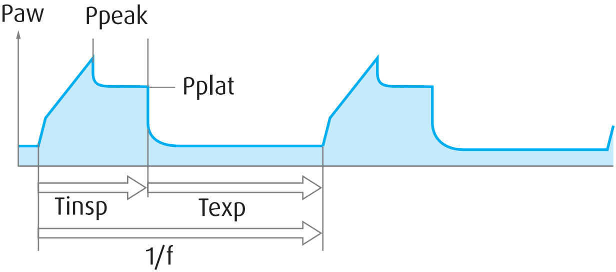


≙	**S/T-PC\PS**
with specified volume ≙	**S/T-PC\vtPS**
pressure support ≙	**S/T-PC\ES**
≙	**S/T-VC\PS**
with specified volume ≙	**S/T-VC\vtPS**
+ pressure support ≙	**S/T-vtPC\PS**
+ pressure support with specified volume ≙	**S/T-vtPC\vtPS**
+ proportional pressure support ≙	**S/T-vtPC\ES**

≙	**SIMV-PC\PS**
with specified volume ≙	**SIMV-PC\vtPS**
pressure support ≙	**SIMV-PC\ES**
≙	**SIMV-VC\PS**
with specified volume ≙	**SIMV-VC\vtPS**
+ pressure support ≙	**SIMV-vtPC\PS**
+ pressure support with specified volume ≙	**SIMV-vtPC\vtPS**
+ proportional pressure support ≙	**SIMV-vtPC\ES**

VCV: Volume-Controlled Ventilation

Chatburn Taxonomy: VC-CMVs
ISO 19223: CMV-VC or A/C-VC



Conventional time-cycled and volume-controlled ventilation with a fixed mandatory minute volume. The intensive care ventilator performs the entire work of breathing in this mode. Using trigger activation and adjustment of the trigger level, mandatory breaths are synchronized with the patient's respiratory efforts and may initiate additional mandatory breaths as needed. The controlled hyperventilation, which is desirable from a therapeutic point of view, results from the guaranteed respiratory minute volume (respiratory rate x tidal volume) and concomitant analgesic sedation.

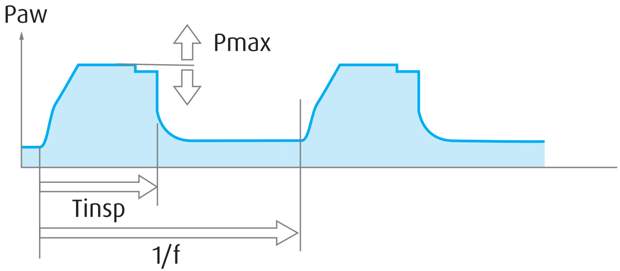
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume (VT)
- Inspiratory oxygen delivery (O_2)
- PEEP
- Pressure limitation (Pmax)
- Trigger
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspiratory flow (flow rate) or inspiratory pause

Manufacturer	Comparable modes	Nomenclature
Air Liquide	Volume-Controlled Ventilation	VCV
Puritan Bennett 980	Assist/Control Volume Control	A/C :VC
Dräger Evita 4 + XL	Intermittent Positive Pressure Ventilation	IPPV, IPPV ass
Dräger Evita V300 – V800	Volume Control – Continuous Mandatory Ventilation	VC-CMV
GE	Volume-Controlled Ventilation	VCV
Hamilton G5 / S1	Continuous Mandatory Ventilation Continuous Mechanical Ventilation	CMV
Hamilton T1 / C1-C3 / C6	Controlled Mandatory Ventilation (C6 only)	CMV
Maquet	Volume Control	VC
Mindray	Volume-Assist/Control Ventilation Mode	V-A/C
Philips	Assist/Control, Volume-Controlled Ventilation	A/C-VCV
Löwenstein Medical elisa 300 - elisa 800VIT	Volume-Controlled Ventilation	VCV

PLV: Pressure-Limited Ventilation

Chatburn Taxonomy: VC-CMVd
ISO 19223: CMV-VC or A/C-VC



PLV is a specific variant of the conventional, volume-controlled ventilation mode VCV. By setting a pressure limit Pmax, inspiratory pressure peaks can be prevented. When the set pressure limit Pmax is reached, the flow is reduced (= decreasing flow). The tidal volume remains constant as long as a short pressure plateau exists.

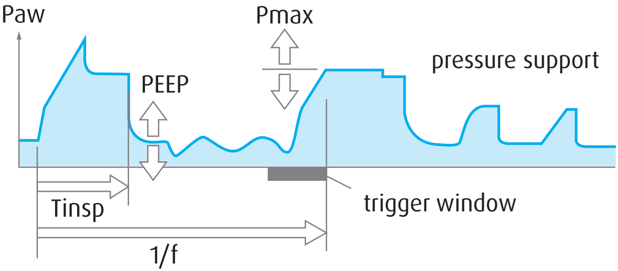
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume (VT)
- Pressure limit (Pmax)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP

Manufacturer	Comparable modes	Nomenclature
Air Liquide	Volume-Controlled Ventilation	VCV (flow pattern)
Puritan Bennett 980	Assist/Control Volume Control (descending ramp)	A/C :VC
Dräger Evita 4 + XL	Intermittent Positive Pressure Ventilation	IPPV, IPPV ass (Pmax)
Dräger Evita V300 – V800	Volume Control – Continuous Mandatory Ventilation	VC-CMV (Pmax)
GE	Volume-Controlled Ventilation	VCV (Plimit)
Hamilton G5 / S1	Continuous Mandatory Ventilation Continuous Mechanical Ventilation	CMV (Flow Pattern)
Hamilton T1 / C1-C3 / C6	Controlled Mandatory Ventilation (C6 only)	CMV (Flow Pattern)
Maquet	–	–
Mindray	Volume-Assist/Control Ventilation Mode	V-A/C (Plimit)
Philips	Assist/Control, Volume-Controlled Ventilation	A/C-VCV (descending ramp)
Löwenstein Medical elisa 300 - elisa 800VIT	Pressure-Limited Ventilation	PLV

VC-SIMV: Synchronized Volume-Controlled Ventilation

Chatburn Taxonomy: VC-IMs,s
ISO 19223: SIMV-VC\PS



Combination of time-cycled, volume-controlled ventilation that allows spontaneous breathing. Mandatory breaths are delivered to stabilize oxygenation and reduce the work of breathing. This method permits spontaneous breathing to take place in between the set mandatory breaths, which can be combined with adjustable pressure support (PSV) to assist the patient's work of breathing.

Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume (VT)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Pressure limit (Pmax)
- Trigger
- Inspiratory flow (flow rate) or inspiratory pause

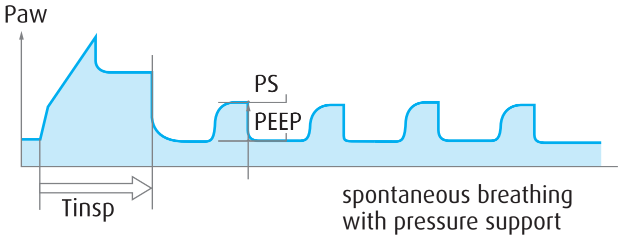
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Synchronized Intermittent Mandatory Ventilation	SIMV
Puritan Bennett 980	Synchronized Intermittent Mandatory Ventilation	SIMV:VC
Dräger Evita 4 + XL	Synchronized Intermittent Mandatory Ventilation	SIMV
Dräger Evita V300 – V800	Synchronized Intermittent Mandatory Ventilation	VC-SIMV
GE	Synchronized Intermittent Mandatory Ventilation – Volume-Controlled	SIMV-VC
Hamilton G5 / S1	Synchronized Intermittent Mandatory Ventilation	SIMV
Hamilton T1 / C1-C3 / C6	Synchronized Intermittent Mandatory Ventilation (C6 only)	SIMV
Maquet	Synchronized Intermittent Mandatory Ventilation – Volume-Controlled	SIMV-VC
Mindray	Volume-controlled SIMV	V-SIMV
Philips	Synchronized Intermittent Mandatory Ventilation, Volume-Controlled Ventilation	SIMV-VCV
Löwenstein Medical elisa 300 - elisa 800VIT	Volume-Controlled: Synchronized Intermittent Mandatory Ventilation	VC-SIMV

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Volume-Controlled Synchronized Intermittent Ventilation	V-SIMV
Löwenstein Medical Luisa	Volume-Controlled Synchronized Intermittent Ventilation	V-SIMV
Löwenstein Medical Prisma Vent	–	–
Resmed Astral 100sc / 150	Volume-Controlled Synchronized Intermittent Ventilation	V-SIMV
Breas Vivo 50 / 60	Volume-Controlled Ventilation with Synchronized Intermittent Mandatory Ventilation	VCV-SIMV

Opt. VCV: Optional Volume-controlled Ventilation

Chatburn Taxonomy: VC-IMVa,s
ISO 19223: SIMV-VC\PS (alternatively: MMV-VC\PS)



Optional volume-controlled ventilation represents a technological advancement over volume-controlled SIMV. Rather than using the set respiratory rate, this mode uses the minimum minute volume (f x VT) as the control variable. The patient's spontaneous breathing effort is constantly monitored and compared to the set minute volume. If spontaneous breathing is unable to deliver the minimum minute volume, a machine breath is triggered. If spontaneous breathing is adequate, no such breaths will be initiated. Instead, respiratory support will be maintained in spontaneous mode, usually with pressure support. In patients with no spontaneous breathing activity, ventilatory support is in the form of continuous mandatory (f x VT) ventilation. In patients who stop breathing for short periods of time, the mandatory ventilation component provides an intelligent back-up system for apnoea ventilation.

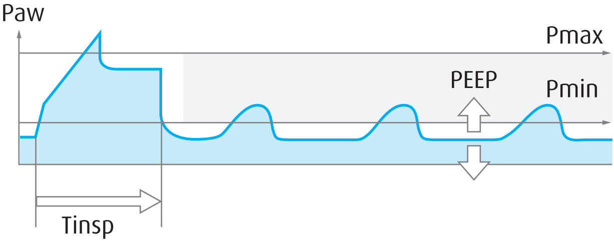
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume (VT)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Gas flow rate (Flow)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Pressure limit (Pmax)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	Mandatory Minute Volume Ventilation	MMV
Dräger Evita V300 – V800	Mandatory Minute Volume Ventilation (Volume Control)	VC-MMV
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Optional Volume-Controlled Ventilation	Opt.VCV

Flex. VCV: Flexible Volume-Controlled Ventilation

Chatburn Taxonomy: VC-IMVa,a
ISO 19223: SIMV-VC\vtPS (alternatively: MMV-VC\vtPS)



A technological advancement over the optional VCV mode with a guaranteed volume for the pressure-supported portion of the spontaneous breaths. Rather than using the set respiratory rate, this mode uses the minimum minute volume (f x VT) as the control variable. The patient's spontaneous breathing effort is constantly monitored and compared to the set minute volume. If spontaneous breathing is unable to deliver the minimum minute volume, a machine breath is triggered. If spontaneous breathing is adequate, no such breaths will be initiated. Instead, respiratory support will be maintained in spontaneous mode with adjustable dynamic pressure support. In patients with no spontaneous breathing activity, ventilatory support is in the form of continuous mandatory (f x VT) ventilation. In patients who stop breathing for short periods of time, the mandatory ventilation component provides an intelligent back-up system for apnoea ventilation. Flexible VCV therefore combines the functional characteristics of optional VCV with those of dynamic PSV.

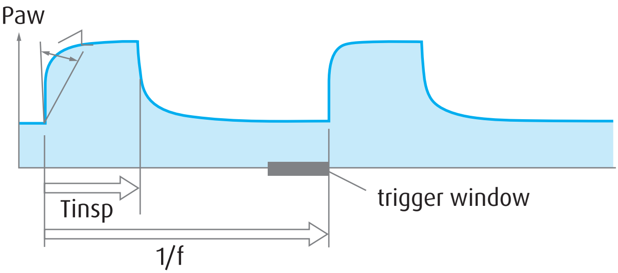
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume (VT), doubling as the target volume for the pressure support of the spontaneous breaths
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Gas flow rate (Flow)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure limit (Pmax)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Flexible VCV	Flex.VCV

PCV: Pressure-Controlled Ventilation

Chatburn Taxonomy: PC-CMVa
ISO 19223: CMV-PC or A/C-PC



Conventional pressure-controlled ventilation. The tidal volume is determined by setting upper and lower pressure levels, and is dependent upon overall pulmonary compliance. The upper pressure level is maintained for the duration of inspiration. In contrast to BiLevel mode, this method does not allow spontaneous breathing at the upper pressure level.

Adjustable basic parameters:

- Respiratory rate (f)
- Peak inspiratory pressure (Pinsp)
- Pressure increase (Ramp)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Trigger

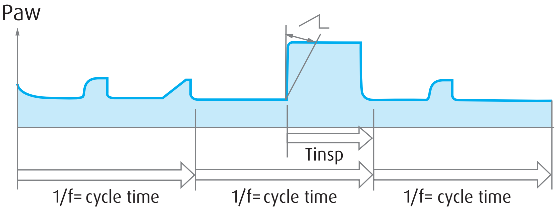
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Pressure-Controlled Ventilation	PCV
Puritan Bennett 980	Assisted/Controlled: Pressure Control	A/C : PC
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	Pressure Control - Continuous Mandatory Ventilation	PC-CMV
GE	Pressure Control Ventilation	PCV
Hamilton G5 / S1	Pressure Control Ventilation	PCV
Hamilton T1 / C1-C3 / C6	Pressure-controlled ventilation	PCV
Maquet	Pressure Control	PC
Mindray	Pressure-Assisted/Controlled ventilation mode	P-A/C
Philips	Assist/Control, Pressure-Controlled Ventilation	A/C-PCV
Löwenstein Medical elisa 300 - elisa 800VIT	Pressure-Controlled Ventilation	PCV

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	(Assisted) Pressure-Controlled Ventilation	A(PCV)
Löwenstein Medical Luisa	(Assisted) Pressure Controlled Ventilation	aPCV / PCV
Löwenstein Medical Prisma Vent	T-mode PCV mode	T PCV
Resmed Astral 100sc / 150	(Assisted) Pressure-Controlled Ventilation	APCV / PCV
Breas Vivo 50 / 60	(Assisted) Pressure-Controlled Ventilation	APCV / PCV

PCV ST

Chatburn Taxonomy: PC-IMVs,s
ISO 19223: S/T-PS/PC(q)



A technological advancement over the conventional pressure-controlled mode. Depending on the patient's spontaneous breathing activity during the set cycle time, either mandatory ventilation is applied or the patient is allowed to breathe spontaneously. Breath cycles are defined by setting a fixed respiratory rate (60/f). If the breathing activity results in the machine's trigger threshold being reached, spontaneous breathing will occur, which can be combined with an adjustable pressure support. If the patient fails to breathe spontaneously during the cycle, the machine will initiate a conventional PCV breath at the end of the calculated cycle time. In patients without spontaneous breathing activity, ventilatory support is delivered in the form of the set mandatory respiration rate. In patients who stop breathing for short periods of time, the mandatory ventilation components provide an intelligent back-up system for apnoea ventilation. This ventilation mode is frequently used as part of non-invasive ventilation or in postoperative respiratory support.

The algorithm ensures a guaranteed minimum respiratory rate and the associated CO_2 removal, which is realised with pressure support or by mandatory pressure-controlled breaths, depending on the spontaneous breathing activity.

Adjustable basic parameters:

- Respiratory rate (f)
- Pressure increase (Ramp)
- Inspiratory to expiratory time ratio (I:E)
- Fraction of inspired oxygen (FiO_2)
- Upper pressure level (Pinsp)
- Pressure support (PS)
- Trigger
- PEEP

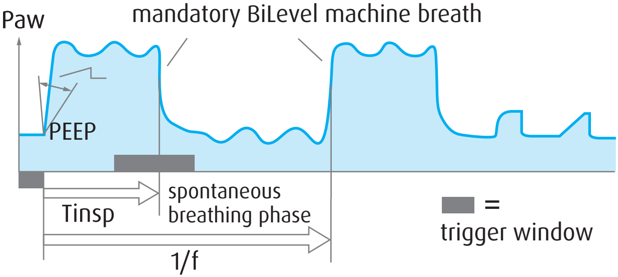
Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	Spontaneous/Timed Non-Invasive Ventilation	NIV-ST
Hamilton T1 / C1-C3 / C6	Spontaneous/Timed Non-Invasive Ventilation	NIV-ST
Maquet	Automode: PC <-> PS	Automode:
Mindray	Pressure Support Ventilation Spontaneous/Timed Ventilation	PSV-S/T
Philips	Spontaneous/Timed	S/T
Löwenstein Medical elisa 300 - elisa 800VIT	Pressure Control Ventilation ST	PCV ST

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Spontaneous/Timed Ventilation	ST
Löwenstein Medical Luisa	Spontaneous/Timed Ventilation	ST
Löwenstein Medical Prisma Vent	ST mode (S = spontaneous, T = timed), with automatic adjustment of the expiratory pressure in response to obstructions	ST autoST mode
Resmed Astral 100sc / 150	Spontaneous timed	ST
Breas Vivo 50 / 60	–	–

BiLevel: Pressure-controlled ventilation that allows spontaneous breathing at any time

Chatburn Taxonomy: PC-IMs,s
ISO 19223: SIMV-PC\PS



A combination of time-cycled and pressure-controlled ventilation that allows spontaneous breathing at both pressure levels. The machine delivers a breath every time the pressure changes from the lower pressure level (PEEP) to the upper pressure level (Pinsp). The tidal volume delivered depends on the difference between the two pressure levels used, and on lung elasticity (compliance). Spontaneous breathing at the lower pressure level can be combined with an adjustable pressure support (PSV).

Adjustable basic parameters:

- Respiratory rate (f)
- Pressure increase (Ramp)
- Inspiratory oxygen delivery (O_2)
- Pressure support (PS)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Upper pressure level (Pinsp)
- PEEP
- Trigger

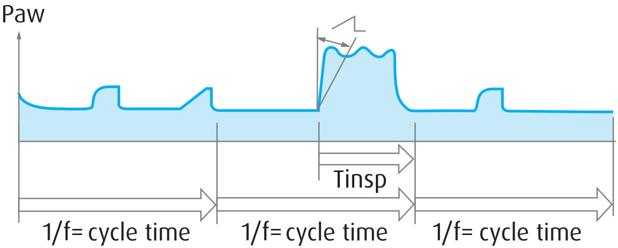
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Pressure-Controlled Ventilation	DUO-LEVELS
Puritan Bennett 980	BiLevel	BiLevel
Dräger Evita 4 + XL	Biphasic Positive Airway Pressure	BIPAP
Dräger Evita V300 – V800	Pressure Control - Biphasic Positive Airway Pressure	PC-BIPAP
GE	BiLevel	BiLevel
Hamilton G5 / S1	Duo Positive Airway Pressure	DuoPAP
Hamilton T1 / C1-C3 / C6	Duo Positive Airway Pressure	DuoPAP
Maquet	Pressure control mode that allows unrestricted spontaneous breathing	BiVent
Mindray	Ventilation with positive airway pressure at two levels	DuoLevel
Philips	–	–
Löwenstein Medical elisa 300 – elisa 800VIT	BiLevel	BiLevel

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Löwenstein Medical Luisa	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Löwenstein Medical Prisma Vent	–	–
Resmed Astral 100sc / 150	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Breas Vivo 50 / 60	Pressure Controlled Ventilation with Synchronized Intermittent Mandatory Ventilation	PCV-SIMV

BiLevel ST

Chatburn Taxonomy: PC-IMVs,s
ISO 19223: S/T-PS/PC(q)



A technological advancement over conventional BiLevel ventilation. Depending on the patient's spontaneous breathing activity during the set cycle time, either mandatory ventilation is applied or the patient is allowed to breathe spontaneously. Breath cycles are defined by setting a fixed respiratory rate (60/f). If the breathing activity results in the machine's trigger threshold being reached, spontaneous breathing will occur, which can be combined with an adjustable pressure support. If the patient fails to breathe spontaneously during the cycle, the machine will initiate a conventional BiLevel breath at the end of the calculated cycle time.

In patients without spontaneous breathing activity, ventilatory support is delivered in the form of the set mandatory respiration rate. In patients who stop breathing for short periods of time, the mandatory ventilation components provide an intelligent back-up system for apnoea ventilation. This ventilation mode is frequently used as part of non-invasive ventilation or in postoperative respiratory support.
The algorithm ensures a guaranteed minimum respiratory rate and the associated CO_2 removal, which is realised with pressure support or by mandatory pressure-controlled breaths, depending on the spontaneous breathing activity.

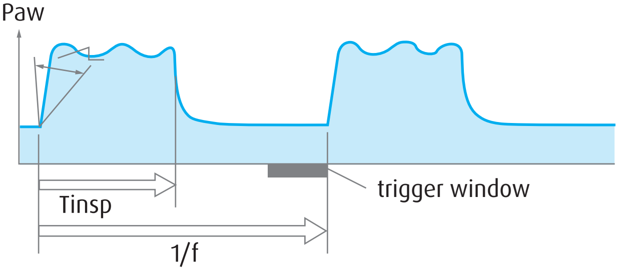
Adjustable basic parameters:

- Respiratory rate (f)
- Upper pressure level (Pinsp)
- Pressure increase (Ramp)
- Pressure support (PS)
- Inspiratory to expiratory time ratio (I:E)
- Trigger
- Fraction of inspired oxygen (FiO_2)
- PEEP

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	BiLevel ST	BiLevel ST

Mand. BiLevel: Mandatory BiLevel

Chatburn Taxonomy: PC-IMVa
ISO 19223: CMV-PC or A/C-PC



Pressure-controlled, time-cycled ventilation that allows spontaneous breathing at the upper pressure levels. BiLevel breaths are time-cycled via the set respiratory rate, but can also be initiated via a trigger function. This mode does not allow additional pressure support, nor does it allow mandatory inspiration time to be shortened in response to an expiratory trigger variable, which would relieve the patient significantly. The tidal volume delivered is determined by the difference between the lower pressure level (PEEP) and the upper pressure level (Pinsp), and is dependent upon lung elasticity (compliance). Mandatory BiLevel is usually used in non-invasive ventilation.

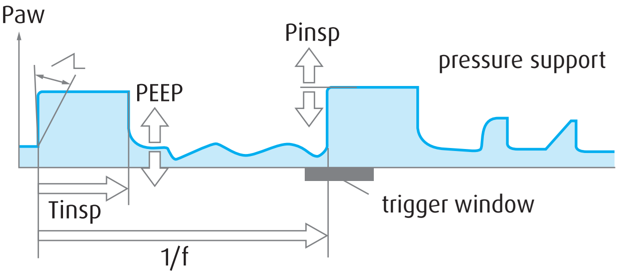
Adjustable basic parameters:

- Respiratory rate (f)
- Peak inspiratory pressure (Pinsp)
- Pressure increase (Ramp)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspiratory oxygen delivery (O_2)
- PEEP
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	Biphasic Positive Airway Pressure Assisted	BIPAPassist
Dräger Evita V300 – V800	Pressure-Controlled Continuous Mandatory Ventilation	PC-CMV PC-AC
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Mandatory BiLevel	Mand. BiLevel

PC-SIMV: Synchronized Pressure-Controlled Ventilation

Chatburn Taxonomy: PC-IMVsr,sr
ISO 19223: SIMV-PC\PS



Combination of time-cycled, pressure-controlled ventilation that allows spontaneous breathing. Mandatory breaths are delivered to stabilize oxygenation and reduce the work of breathing. This method permits spontaneous breathing to take place in between mandatory breaths, Spontaneous breathing can be combined with an adjustable pressure support (PSV).

Adjustable basic parameters:

- Respiratory rate (f)
- Peak inspiratory pressure (Pinsp)
- Pressure increase (Ramp)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Trigger

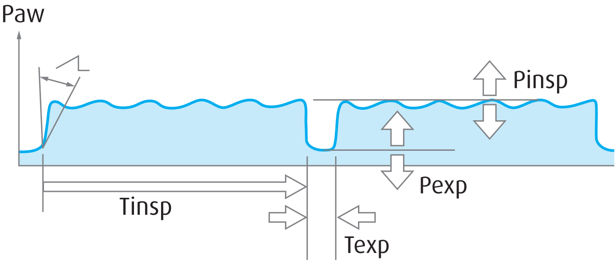
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Synchronized Intermittent Mandatory Pressure-Monitored Ventilation	PSIMV
Puritan Bennett 980	Synchronized Intermittent Mandatory Ventilation	SIMV: PC
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	Pressure Control – Synchronized Intermittent Mandatory Ventilation	PC-SIMV
GE	Synchronized Intermittent Mandatory Ventilation – Pressure Control	SIMV-PC
Hamilton G5 / S1	Pressure - Synchronized Intermittent Mandatory Ventilation	P-SIMV
Hamilton T1 / C1-C3 / C6	Pressure-controlled SIMV (C6 only)	P-SIMV+
Maquet	Synchronized Intermittent Mandatory Ventilation – Pressure Control	SIMV-PC
Mindray	Pressure-regulated SIMV mode	P-SIMV
Philips	Synchronized Intermittent Mandatory Ventilation, Pressure-Controlled Ventilation	SIMV-PCV
Löwenstein Medical elisa 300 - elisa 800VIT	Pressure Control - Synchronized Intermittent Mandatory Ventilation	PC-SIMV

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Löwenstein Medical Luisa	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Löwenstein Medical Prisma Vent	–	–
Resmed Astral 100sc / 150	Pressure-Controlled Synchronized Intermittent Ventilation	P-SIMV
Breas Vivo 50 / 60	Pressure-Controlled Ventilation with Synchronized Intermittent Mandatory Ventilation	PCV-SIMV

PC-APRV: Pressure Control - Airway Pressure Release Ventilation

Chatburn Taxonomy: PC-IMs,s
ISO 19223: IMV-PC



With this modified BiLevel mode, the patient is allowed to breathe spontaneously at the upper pressure levels (inverse I:E ratio), which are usually maintained throughout a long phase. CO_2 elimination is achieved by briefly lowering airway pressure to the lower pressure level (PEEP). These brief expiratory relief phases are referred to as pressure release and help to remove CO_2 from those areas of the lungs that are ventilated more quickly. The short expiratory phases (Texp) also help to prevent the collapse of these lung areas.

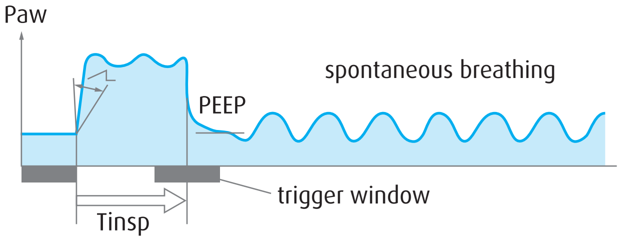
Adjustable basic parameters:

- Peak inspiratory pressure (Pinsp)
- Pressure increase (Ramp)
- Inspiratory time (Tinsp)
- Expiratory time (Texp)
- Inspired oxygen delivery (O_2)
- PEEP
- Trigger
- (Switch)-Flow for AutoRelease if applicable

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	BiLevel with short expiration (release) time	APRV
Dräger Evita 4 + XL	Airway Pressure Release Ventilation	APRV
Dräger Evita V300 – V800	Pressure Control - Airway Pressure Release Ventilation	PC-APRV
GE	Airway Pressure Release Ventilation	APRV
Hamilton G5 / S1	Airway Pressure Release Ventilation	APRV
Hamilton T1 / C1-C3 / C6	Airway Pressure Release Ventilation	APRV
Maquet	BiVent with short expiration (release) time	BiVent-APRV
Mindray	Ventilation with brief, intermittent airway pressure release	APRV
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Airway Pressure Release Ventilation	PC-APRV

Opt. BiLevel: Optional BiLevel

Chatburn Taxonomy: PC-IMVda,s
ISO 19223: SIMV-PC\PS (alternatively: MMV-PC\PS)



A technological advancement over conventional BiLevel ventilation. Depending on the set minute volume (f x VT, which results from the differential pressure), either mandatory breaths are initiated or the patient is allowed to breathe spontaneously. Rather than using the set respiratory rate, this mode uses the set minimum minute volume as the control variable. The patient's spontaneous breathing effort is constantly monitored and compared to the set minute volume. If spontaneous breathing is unable to deliver the minimum minute volume, a machine breath is triggered. If spontaneous breathing is adequate, no such breaths will be initiated. Instead, respiratory support will be maintained in spontaneous mode with adjustable pressure support. In patients with no spontaneous breathing activity, ventilatory support is delivered in the form of a minimum minute volume, and includes all the benefits of BiLevel ventilation. In patients who stop breathing for short periods of time, the mandatory ventilation components provide an intelligent back-up system for apnoea ventilation.

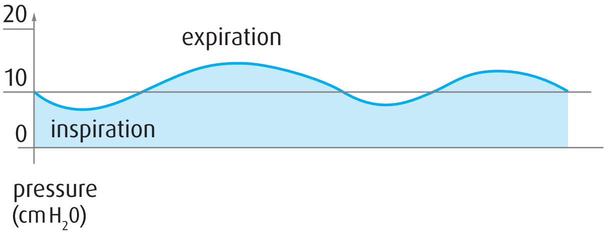
Adjustable basic parameters:

- Respiratory rate (f)
- Peak inspiratory pressure (Pinsp)
- Pressure increase (Ramp)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	Minimum Mandatory Ventilation	MMV
Dräger Evita V300 – V800	Pressure Control: Minimum Mandatory Ventilation	PC-MMV
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Optional BiLevel	Opt. BiLevel

CPAP: Continuous Positive Airway Pressure

Chatburn Taxonomy: PC-CSVs
ISO 19223: CPAP or CSV-ACAP



Spontaneous breathing modes maintain positive pressure throughout the ventilation cycle, but particularly during the expiratory phase (= PEEP).

Adjustable basic parameters:

- Inspired oxygen delivery (O_2)
- PEEP
- Trigger
- Apnoea ventilation parameters

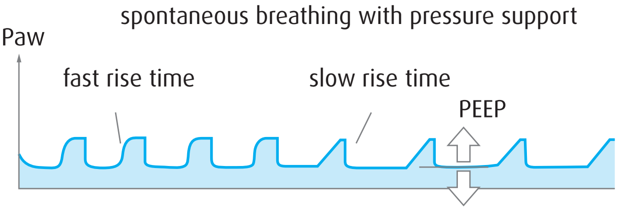
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Continuous Positive Airway Pressure	CPAP
Puritan Bennett 980	Spontaneous Breathing	Spont.
Dräger Evita 4 + XL	Continuous Positive Airway Pressure	CPAP
Dräger Evita V300 – V800	Spontaneous - Continuous Positive Airway Pressure	SPN-CPAP
GE	Continuous Positive Airway Pressure	CPAP
Hamilton G5 / S1	Spontaneous Breathing	Spont.
Hamilton T1 / C1-C3 / C6	Spontaneous Breathing	Spont.
Maquet	Continuous Positive Airway Pressure	Spont./ CPAP
Mindray	(indirect)	–
Philips	Continuous Positive Airway Pressure	CPAP
Löwenstein Medical elisa 300 - elisa 800VIT	Continuous Positive Airway Pressure	CPAP

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Ventilation with Continuous Positive Airway Pressure	CPAP
Löwenstein Medical Luisa	Continuous Positive Airway Pressure	CPAP
Löwenstein Medical Prisma Vent	Continuous Positive Airway Pressure	CPAP
Resmed Astral 100sc / 150	Continuous Positive Airway Pressure	CPAP
Breas Vivo 50 / 60	Continuous Positive Airway Pressure	CPAP

PSV: Spontaneous Breathing with Pressure Support Ventilation

Chatburn Taxonomy: PC-CSVs
ISO 19223: CSV-PS



Conventional form of spontaneous breathing with adjustable pressure support.

In spontaneously breathing patients, pressure support (PS) is delivered at a fixed pressure value. This partially replaces the patient's work of breathing and allows deeper spontaneous breaths. Pressure support is initiated once a relevant trigger threshold has been reached. While the patient initiates inspiration, the intensive care ventilator controls the timing of expiration (PS Endflow).

Adjustable basic parameters:

- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Pressure increase (Ramp)
- Trigger
- Apnoea ventilation parameters
- PS Endflow

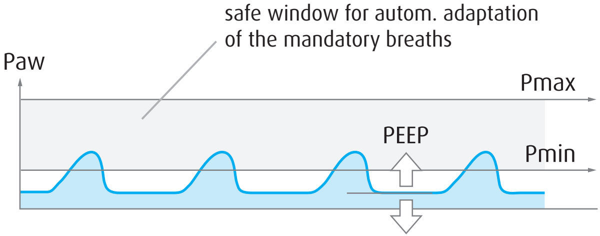
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Pressure Support Ventilation	PSV
Puritan Bennett 980	Pressure Support	PS
Dräger Evita 4 + XL	Assisted Spontaneous Breathing	ASB
Dräger Evita V300 – V800	Pressure Controlled - Pressure Support Ventilation	SPN-CPAP/PS
GE	Pressure Support Ventilation	CPAP/PSV
Hamilton G5 / S1	Pressure support ventilation for spontaneous breathing	Spont
Hamilton T1 / C1-C3 / C6	Pressure support ventilation for spontaneous breathing	Spont
Maquet	Pressure Support	PS
Mindray	Pressure Support Ventilation	CPAP/PSV
Philips	Pressure Support Ventilation; spontaneous breathing with pressure support	PSV
Löwenstein Medical elisa 300 - elisa 800VIT	Pressure Support Ventilation	PSV

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Pressure Support Ventilation	PSV
Löwenstein Medical Luisa	Spontaneous mode PSV mode	S PSV
Löwenstein Medical Prisma Vent	Spontaneous mode PSV mode	S PSV
Resmed Astral 100sc / 150	Pressure Support Ventilation	PSV
Breas Vivo 50 / 60	Pressure Support Ventilation	PSV

Dyn. PSV: Dynamic Pressure Support Ventilation

Chatburn Taxonomy: PC-CSVa
ISO 19223: CSV-vtPS



A technological advancement over conventional PSV. In spontaneously breathing patients, pressure support is delivered in a dynamic manner (for each breath, the level of pressure support delivered is adjusted to meet a set target volume). This partially replaces the patient's work of breathing and allows deeper breaths. Pressure support is dependent upon the set target volume (VT), the extent of the patient's work of breathing, and overall pulmonary compliance. A 'safe window' is created (Pmax and Pmin), within which the level of pressure support required adjusts freely on a breath-by-breath basis, at increments not exceeding 3 mbar. This support mode is initiated once a relevant trigger threshold has been reached. While the patient initiates inspiration, the intensive care ventilator controls the timing of expiration (PS Endflow).

Adjustable basic parameters:

- Inspiratory oxygen delivery (O_2)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- PEEP
- Trigger
- PS Endflow

- Lower pressure limit (Pmin)
- Pressure increase (Ramp)
- Parameter for apnoea ventilation

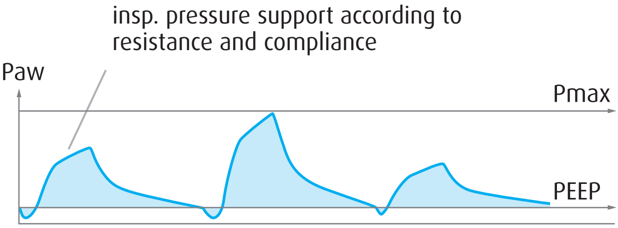
Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	Volume Support	VS
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	Spontaneous - Continuous Positive Airway Pressure (Volume Support)	SPN-CPAP/ VS
GE	Volume Support	VS
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	Volume Support	VS
Mindray	Volume Support Ventilation	VS
Philips	Average Volume Assured Pressure Support	AVAPS
Löwenstein Medical elisa 300 - elisa 800VIT	Dynamic Pressure Support Ventilation	Dyn. PSV

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Pressure Support Ventilation with target volume	PSV VT
Löwenstein Medical Luisa	PSV with target volume	PSV
Löwenstein Medical Prisma Vent	PSV with target volume	PSV
Resmed Astral 100sc / 150	PSV with target volume	PSV
Breas Vivo 50 / 60	Pressure Support Ventilation with target volume	PSV(TgV)

Prop. PSV: Proportional Pressure Support Ventilation

Chatburn Taxonomy: PC-CSVr
ISO 19223: CSV-ES


insp. pressure support according to resistance and compliance
Paw
Pmax
PEEP

A technological advancement over conventional PSV. In spontaneously breathing patients, pressure support is delivered at a level that is proportional to the degree of compensation required in relation to flow resistance (Flow Support) and airway resistance (Volume Support). This partially replaces the patient's work of breathing and allows deeper breaths. The level of pressure support delivered varies on a breath-by-breath basis, and is dependent on flow and inspired volume. For safety reasons, the upper pressure limit (Pmax) must be set, and apnoea ventilation setting must be selected.

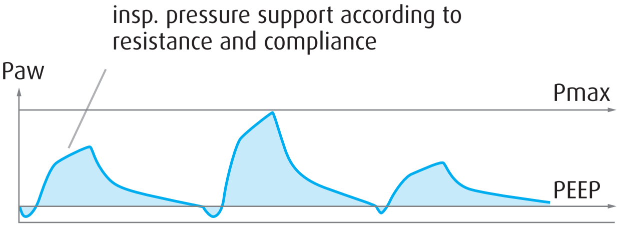
Adjustable basic parameters:

- Flow support
- Volume support
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure limit (Pmax)
- Apnoea ventilation

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	Proportional Pressure Support	PPS
Dräger Evita V300 – V800	Spontaneous Breathing - Proportional Pressure Support	SPN-PPS
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	Proportional Pressure Ventilation	PPV
Löwenstein Medical elisa 300 - elisa 800VIT	Proportional Pressure Support Ventilation	Prop. PSV

PAPS (Proportional Adaptive Pressure Support)

Chatburn Taxonomy: PC-CSVr
ISO 19223: CSV-ES


insp. pressure support according to resistance and compliance
Paw
Pmax
PEEP

Contrary to the fixed pressure support in the PSV mode, the spontaneously breathing patient receives proportional pressure support in the PAPS mode. The effective pressure support in this mode adapts to the elevated elastic and restrictive resistances.

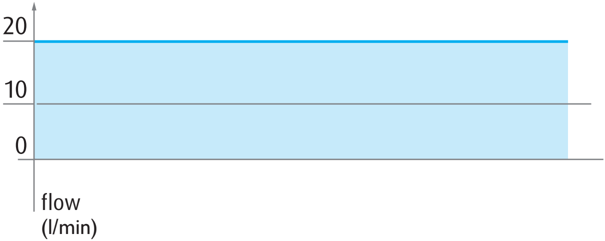
Tyler (1962) and M. Younes (from 1987) in Winnipeg established the fundamentals of this method. A special algorithm determines the work of breathing due to higher flow and airway resistance on a breath-by-breath basis and regulates the adaptive pressure support required for compensation. The algorithms used by the manufacturers differ in detail and particularly with respect to how the compliance and resistance in spontaneously breathing patients is determined.
Pressure support with PAPS is thus more physiological and offers greater comfort for the patient. The adjustable level of support allows the mode to be adapted during the weaning process.

Basic parameters:

- Inspiratory oxygen delivery (O_2)
- PEEP
- PS TImax
- Trigger
- Pmax
- Degree of compensation (%)

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	Proportional Assist Ventilation	PAV+
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Proportional Adaptive Pressure Support	PAPS

HFOT: High Flow Oxygen Therapy



In high-flow O_2 therapy, actively heated and humidified inspiratory gas (usually 20 to 60 litres per minute) with an appropriate oxygen concentration is applied via a nasal cannula. The focus of high-flow oxygen therapy is on different mechanisms:

- reliable, constant inspiratory oxygen concentration
- anatomic dead space CO_2 washout
- generating a small PEEP
- improving the ventilation - perfusion ratio
- expanding the expiratory lung volume, reducing the work of breathing
- improving secretion clearance by actively heated and humidified respiratory gas

High-flow O_2 therapy offers the advantages of optimum patient comfort, continued communication ability, and the possibility of food intake. Since the method does not use an NIV mask, it is usually well tolerated by the patient, and mask-related complications are excluded.
Details of the interface for non-invasive ventilation in acute respiratory failure and of the significance for weaning still need to be clarified.

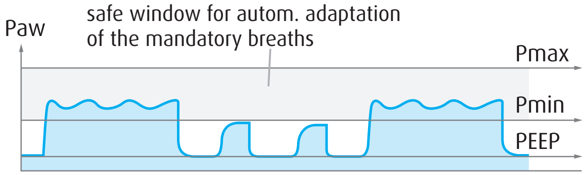
Manufacturer	Comparable modes	Nomenclature
Air Liquide	HighFlow Therapy	HighFlow Therapy
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	O_2 therapy	O_2 therapy
GE	–	–
Hamilton G5 / S1	Highflow O_2	Highflow O_2
Hamilton T1 / C1-C3 / C6	Highflow O_2 (not C2)	Highflow O_2
Maquet	–	–
Mindray	–	–
Philips	–	–
Salvia elisa 300 - elisa 800VIT	High Flow Oxygen Therapy	HFOT

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove: EO-150	Continuous flow	C-Flow
Löwenstein Medical Luisa	High-flow mode	HFT
Löwenstein Medical: Prisma Vent 50C	High-flow mode	HFT
Resmed: Astral 100sc / 150	–	–
Breas: Vivo 50 / 60	–	–

Dynamic BiLevel

Chatburn Taxonomy: PC-IMVa,s
ISO 19223: SIMV-vcPC\PS



The inspiratory pressure of the machine breaths increases in line with the set target volume and compliance.
A technological advancement over the well-known BiLevel mode with a guaranteed volume for the machine breaths. Spontaneous breathing at the lower pressure level can occur at the CPAP level or it can be pressure-supported. Instead of using the upper pressure level (Pinsp), the machine is programmed using a desired target volume. The machine delivers a breath every time the pressure changes from the lower pressure level (PEEP) to the upper pressure level (Pinsp). The exact level of pressure delivered depends on the set target volume (VT), and on lung elasticity (compliance). A safe window is created (Pmax and Pmin), within which the upper pressure level adjusts freely on a breath-by-breath basis and at increments not exceeding 3 mbar. Dynamic BiLevel ventilation offers simpler operation and minimizes the risk of volutrauma or dead space ventilation following a change in compliance.

Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Trigger
- PS Endflow
- Pressure increase (Ramp)

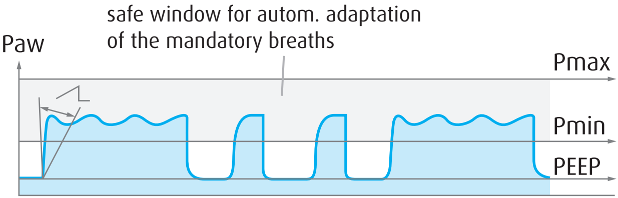
Manufacturer	Comparable modes	Nomenclature
Air Liquide	Pressure-Regulated Volume-Controlled	PRVC
Puritan Bennett 980	Adaptation of the target pressure in order to deliver the set volume	VC+
Dräger Evita 4 + XL	Synchronized Intermittent Mandatory Ventilation with Autoflow option	SIMV-Auto-flow
Dräger Evita V300 – V800	Volume Controlled - Synchronized Intermittent Mandatory Ventilation with Autoflow option, PC-SIMV with Volume Guarantee	VC-SIMV-Autoflow
GE	BiLevel with Volume Guarantee, Synchronized Intermittent Mandatory Ventilation, Pressure Controlled, with Volume Guarantee	PC-SIMV VG
Hamilton G5 / S1	Adaptive Pressure Ventilation	APVsimv/ SIMV+
Hamilton T1 / C1-C3 / C6	Volume-Controlled, Adaptive Pressure: SIMV	APVsimv/ SIMV+
Maquet	Pressure-Regulated Volume-Controlled Ventilation	PRVC
Mindray	Pressure-Regulated Volume-Controlled Ventilation	PRVC-SIMV
Philips	Pressure-Regulated, Volume-Controlled	PRVC
Löwenstein Medical elisa 300 - elisa 800VIT	Dynamic BiLevel	Dyn. BiLevel

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	Volume Controlled Synchronized Intermittent Mandatory Ventilation	V-SIMV
Löwenstein Medical Luisa	Volume Controlled Synchronized Intermittent Mandatory Ventilation	V-SIMV
Löwenstein Medical Prisma Vent	–	–
Resmed Astral 100sc / 150	Volume Controlled Synchronized Intermittent Mandatory Ventilation	V-SIMV
Breas Vivo 50 / 60	Volume Controlled Synchronized Intermittent Mandatory Ventilation	V-SIMV

Dual BiLevel

Chatburn Taxonomy: PC-IMVa,a
ISO 19223: SIMV-vcPC\vcPS



Both inspiratory pressure support and the inspiratory pressure level of the machine breaths correspond to the set target volume and compliance.
A technological advancement over the well-known BiLevel mode with a guaranteed volume for the mandatory and the spontaneous components of ventilation. The target volume determines the change from the lower pressure level (PEEP) to the upper pressure level (Pinsp), and controls the extent of the pressure support delivered. A safe window is created (Pmax and Pmin), within which the upper pressure level or the pressure support adjusts freely on a breath-by-breath basis and at increments not exceeding 3 mbar. Dual BiLevel, therefore, combines the functional characteristics of dynamic BiLevel with those of dynamic PSV.

Adjustable basic parameters:

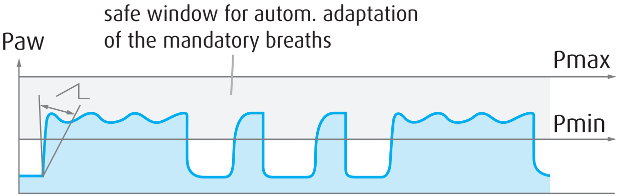
- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)

- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Trigger
- PS Endflow

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Dual BiLevel	Dual BiLevel

Flexible BiLevel

Chatburn Taxonomy: PC-IMVda,a
ISO 19223: SIMV-vcPC\vcPS (alternatively: MMV-vtPC\vcPS)



A technological advancement over optional BiLevel ventilation. However, rather than using the set respiratory rate, this mode uses the minimum minute volume (f x VT) as the control variable. The patient's spontaneous breathing effort is constantly monitored and compared to the set minute volume. If spontaneous breathing is unable to deliver the minimum minute volume, a machine breath is triggered. If spontaneous breathing is adequate, no such breaths will be initiated. Instead, respiratory support will be maintained in spontaneous mode with dynamic pressure support. In patients with no spontaneous breathing activity, ventilatory support is in the form of continuous mandatory ventilation. The set target volume determines the change from the lower pressure level (PEEP) to the upper pressure level (Pinsp), and controls the extent of the pressure support delivered (PSV). A safe window is created (Pmax and Pmin), within which the upper pressure level and/or the pressure support adjusts freely on a breath-by-breath basis and at increments not exceeding 3 mbar. In patients who stop breathing for short periods of time, the mandatory ventilation component provides an intelligent back-up system for apnoea ventilation. Flexible BiLevel therefore combines the functional characteristics of optional BiLevel with those of dynamic PSV.

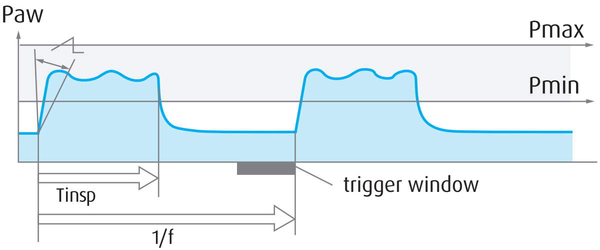
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure increase (Ramp)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Flexible BiLevel	Flex. BiLevel

VA BiLevel: Volume-adaptive BiLevel

Chatburn Taxonomy: PC-IMVa,s
ISO 19223: CMV-vtPC oder A/C-vcPC



A technological advancement over the well-known BiLevel mode with a guaranteed volume for the machine breaths. Additional breaths can be initiated by triggering.
Dynamic BiLevel breaths are time-cycled via the set respiratory rate, but can also be initiated via a trigger function. This mode does not allow additional pressure support, nor does it allow mandatory inspiration time to be shortened in response to an expiratory trigger variable, which would relieve the patient significantly. The exact level of pressure delivered depends on the set target volume (VT) and on lung elasticity (compliance). A safe window is created (Pmax and Pmin), within which the upper pressure level adjusts freely on a breath-by-breath basis and at increments not exceeding 3 mbar. Volume-adaptive BiLevel ventilation reduces operator interventions and minimizes the risk of volutrauma or dead space ventilation following a change in compliance.

Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Pressure increase (Ramp)
- Inspiratory oxygen delivery (O_2)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)
- PEEP
- Trigger
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)

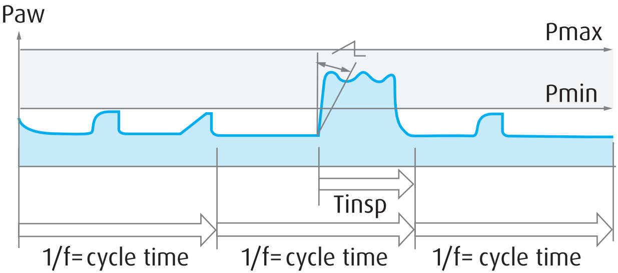
Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	Intermittent Positive Pressure Ventilation with Autoflow option	IPPV-Autoflow
Dräger Evita V300 – V800	Volume Controlled - Continuous Mandatory Ventilation with Autoflow option	VC-CMV-Autoflow
GE	–	–
Hamilton G5 / S1	Adaptive Pressure Ventilation: Continuous Mandatory Ventilation	APVcmv/ (S)CMV+
Hamilton T1 / C1-C3 / C6	Volume-Controlled, Adaptive Pressure Ventilation	APVcmv/ (S)CMV+
Maquet	–	–
Mindray	Pressure-Regulated Volume Control	PRVC
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Volume-adaptive BiLevel	VA BiLevel

Homecare:

Manufacturer	Comparable modes	Nomenclature
Eove EO-150	(ST mode with target volume)	(ST VT)
Löwenstein Medical Luisa	PCV with target volume	PCV
Löwenstein Medical Prisma Vent	T mode with target volume	T
Resmed Astral 100sc / 150	(Assisted) Pressure-Controlled Ventilation with target volume	APCV / PCV
Breas Vivo 50 / 60	Assisted Pressure-Controlled Ventilation with target volume	PCV(A+TgV)

Dynamic BiLevel ST

Chatburn Taxonomy: PC-IMVa,a
ISO 19223: S/T-PS/vtPC



A technological advancement over the well-known BiLevel mode with a guaranteed volume for the machine breaths. Spontaneous breathing can occur at the CPAP level or it can be pressure-supported. Depending on the patient's spontaneous breathing activity during the set cycle time (60/f), either mandatory ventilation is applied or the patient is allowed to breathe spontaneously. Instead of using the upper pressure level (Pinsp), the machine is programmed using a desired target volume. The machine delivers a breath every time the pressure changes from the lower pressure level (PEEP) to the upper pressure level (Pinsp). The exact level of pressure delivered depends on the set target volume (VT), and on lung elasticity (compliance). A safe window is created (Pmax and Pmin), within which the upper pressure level adjusts freely on a breath-by-breath basis and at increments not exceeding 3 mbar. Dynamic BiLevel ventilation offers simpler operation and minimizes the risk of volutrauma or dead space ventilation following a change in compliance.

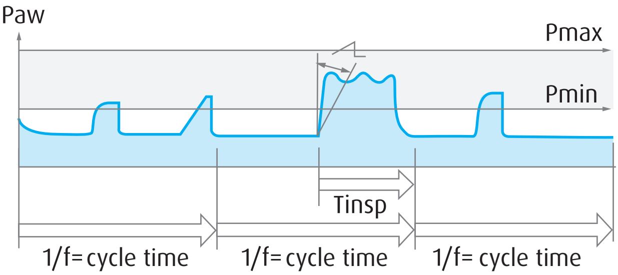
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Dynamic BiLevel ST	Dyn. BiLevel ST

Dual BiLevel ST

Chatburn Taxonomy: PC-IMVa,a
ISO 19223: S/T-vtPS/vtPC



A technological advancement over the well-known BiLevel mode with a guaranteed volume for the machine-driven and the spontaneous component of ventilation. Depending on the patient's spontaneous breathing activity during the set cycle time, either mandatory ventilation is applied or the patient is allowed to breathe spontaneously.

Breath cycles are defined by setting a fixed respiratory rate (60/f). If spontaneous breathing results in the machine's trigger threshold being reached, pressure support with volume guarantee (= dynamic PSV) will be provided for the spontaneous breath. If the patient fails to breathe spontaneously during the cycle, the machine will initiate a conventional BiLevel breath with volume guarantee (= dynamic BiLevel) at the end of the calculated cycle time. In patients without spontaneous breathing activity, ventilatory support is delivered in the form of the set minimum minute volume. In patients who stop breathing for short periods of time, the mandatory ventilation components provide an intelligent back-up system for apnoea ventilation.

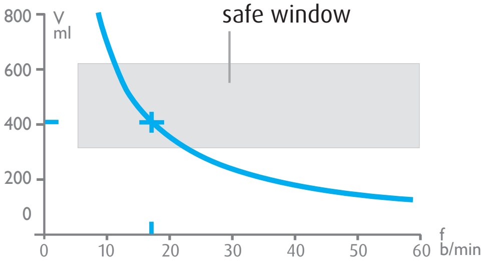
Adjustable basic parameters:

- Respiratory rate (f)
- Tidal volume as target volume (VT)
- Upper pressure limit (Pmax)
- Lower pressure limit (Pmin)
- Inspiratory to expiratory time ratio (I:E) or inspiratory time (Tinsp)
- Inspired oxygen delivery (O_2)
- PEEP
- Pressure support (PS)
- Trigger

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	–	–
Hamilton T1 / C1-C3 / C6	–	–
Maquet	Automode: PRVC <-> VS	Automode:
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Dual BiLevel ST	Dual BiLevel ST

WOBOV (Work Of Breathing Optimized Ventilation)

Chatburn Taxonomy: PC-IMVoi,oi
ISO 19223: SIMV-vtPC\vtPS (alternatively: MMV-vtPC\vtPS)



WOBOV is a universal mode, promoting spontaneous breathing and affording adequate minute ventilation, a breathing pattern with optimum energy efficiency and compliance with the specified lung-protection rules. In this mode, the breathing pattern associated with the highest energy efficiency is continuously calculated and ventilation control (modified Otis equation) is adapted accordingly. This control method is based on the insights of Rohrer (1925) and Otis et al. (1950), according to which an energetically optimal breathing pattern reduces negative work of breathing and promotes spontaneous breathing, thereby preventing dead space ventilation.

At the same time it supports spontaneous breathing by automatically reducing the assistance provided by the ventilator. In the case of insufficient ventilation, WOBOV will gradually increase ventilator support, i.e., the algorithm will compensate the deficit up to the pre-set minute ventilation when necessary. In this mode, both pressure-controlled ventilation with volume guarantee (comparable to dynamic BiLevel) and pressure-assisted spontaneous breathing with volume guarantee (dynamic PSV) are available.

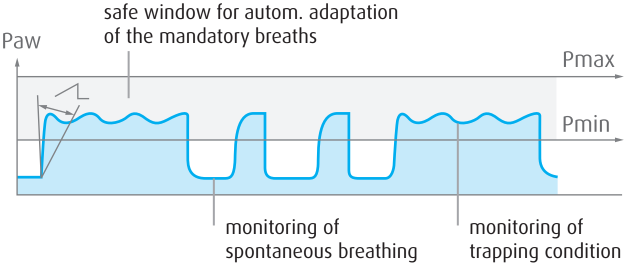
Adjustable basic parameters:

- Body height
- Inspiratory oxygen delivery (O_2)
- PEEP
- PS TImax
- Trigger
- Pmax
- Pmin
- %MV

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	ASV – Adaptive Support Ventilation	ASV
Hamilton T1 / C1-C3 / C6	ASV – Adaptive Support Ventilation	ASV
Maquet	–	–
Mindray	Adaptive minute ventilation	RMV
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	Work Of Breathing Optimized Ventilation	WOBOV

ALPV: Adaptive Lung Protection Ventilation

Chatburn Taxonomy: PC-IMVoi,oi
ISO 19223: SIMV-vtPC\vtPS (alternatively: MMV-vtPC\vtPS)


safe window for autom. adaptation of the mandatory breaths
Paw
Pmax
Pmin
monitoring of spontaneous breathing
monitoring of trapping condition

In contrast to 'conventional' ASV, the ALPV mode does not control the ventilation based on the OTIS equation, but according to the current guidelines for lung-protective ventilation.

In this mode, pressure-controlled ventilation with volume guarantee (comparable to dynamic BiLevel) is combined with pressure-supported spontaneous breathing with volume guarantee (dynamic PSV) in such a way that a specified tidal volume (e.g., 6mL/kg referred to the ideal body weight) is reached as the target for both mandatory ventilation and pressure-supported spontaneous breaths.

ALPV not only permits spontaneous breathing activity but promotes it by automatically reducing the assistance provided by the ventilator in a controlled way. In the case of insufficient ventilation, ALPV will compensate the deficit up to the pre-set minute ventilation (%min). If the patient's spontaneous breathing activity decreases, ventilator assistance up to the set minute ventilation is resumed in the ALPV mode.

The ALPV mode thus combines the known advantages of hybrid closed-loop ventilation with the current requirements of lung-protective ventilation.

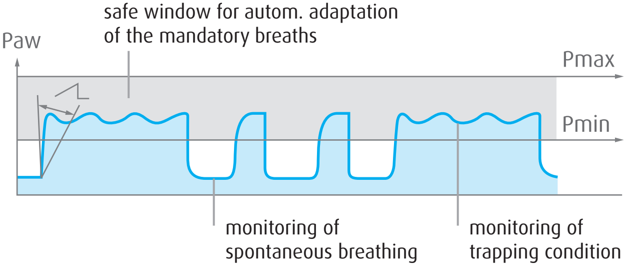
Adjustable basic parameters:

- Body height
- PEEP
- Trigger
- VT/IBW
- Inspiratory oxygen delivery (O_2)
- Pmin
- PS TImax
- Exp Trigger
- Pmax
- %MV

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	ASV – Adaptive Support Ventilation	ASV 1.1
Hamilton T1 / C1-C3 / C6	ASV – Adaptive Support Ventilation	ASV 1.1
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	ALPV – Adaptive Lung Protection Ventilation	ALPV

INTELLiVENT-ASV

Chatburn Taxonomy: PC-IMVoi,oi
ISO 19223: SIMV-vtPC\vtPS (alternatively: MMV-vtPC\vtPS)


safe window for autom. adaptation of the mandatory breaths
Paw
Pmax
Pmin
monitoring of spontaneous breathing
monitoring of trapping condition

INTELLiVENT-ASV builds on the established ASV mode.
Once the patient's weight has been entered, the machine uses the Radford nomogram to calculate the anatomical dead space. Oxygenation and CO_2 elimination are based on the specified alveolar respiratory minute volume and on the desired support factor (% minute volume). After input of Pmax, control algorithms that are specific to each ventilation scenario are applied and optimized by the Otis equation.
By adjusting parameters, the user creates a safe window with a pre-set minimum minute volume, which guarantees a suitable breathing pattern:

- Maximum allowable tidal volume as determined by Pmax
- Minimum allowable tidal volume (2.2 ml per kg of body weight dead-space volume x 2)
- Maximum respiratory rate
- Minimum respiratory rate (≥ 5/min)
- Control of the inspiratory to expiratory time ratio (I:E) to prevent intrinsic PEEP at the end of the measured expiratory time constant (RCexp)

IntelliVent-ASV uses closed-loop ventilation that is additionally controlled using end-tidal CO_2 and pulse oximetry.

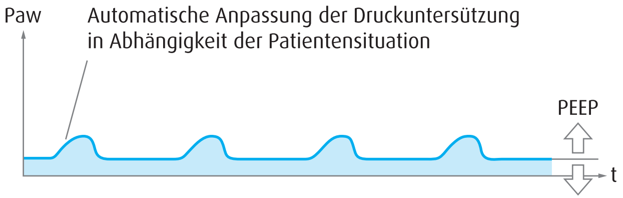
Adjustable basic parameters:

- Body weight, gender
- Inspiratory oxygen delivery (O_2)
- PEEP
- %minute volume (desired minimum minute volume in %, e.g., 100ml kgBW)
- Pressure limit (Pmax -10)

Manufacturer	Comparable modes	Nomenclature
Air Liquide	–	–
Puritan Bennett 980	–	–
Dräger Evita 4 + XL	–	–
Dräger Evita V300 – V800	–	–
GE	–	–
Hamilton G5 / S1	Adaptive support ventilation with activated INTELLiVENT function	INTELLiVENT ASV
Hamilton T1 / C1-C3 / C6	Adaptive support ventilation with activated INTELLiVENT function (C3 / C6 only)	INTELLiVENT ASV
Maquet	–	–
Mindray	–	–
Philips	–	–
Löwenstein Medical elisa 300 - elisa 800VIT	–	–

SmartCare

Chatburn Taxonomy: PC-CSVi


Paw
Automatische Anpassung der Druckuntersützung in Abhängigkeit der Patientensituation
PEEP
t

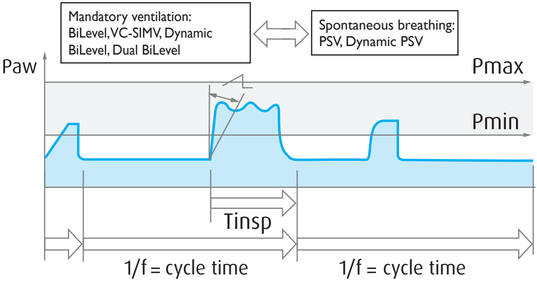
SmartCare is an automated weaning system. It automatically adapts the pressure support to a target range, and follows an automated weaning protocol. The patient must be able to maintain an adequate level of spontaneous breathing. The intensive care ventilator uses an algorithm to constantly adjust the pressure support provided. The end-tidal CO_2 level is continuously analysed at the same time. Once the set target values have been achieved, SmartCare switches to monitoring mode, and attempts to wean the patient from the ventilator.

Adjustable basic parameters:

- Body weight
- Ventilation access (endotracheal tube/tracheal cannula)
- Humidification (active/passive)
- COPD (YES/NO)
- Neurological disorder (YES/NO)
- Activation of tube compensation recommended (for body weight > 35 kg)
- Alarm limits

Automode

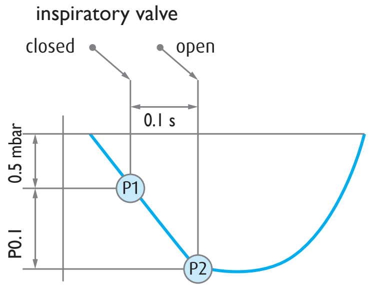
Chatburn Taxonomy: VC-IMd,a
ISO 19223: S/T-PS/PC(q)



Automode is a closed-loop mode of ventilation. It is intended to improve the interaction between the intensive care ventilator and patient and to reduce operator interventions. It combines mandatory modes and spontaneous breathing modes. If two spontaneous breathing attempts are identified or if spontaneous breathing results in the machine's trigger threshold being reached, the machine will assist the spontaneous breathing with pressure support. If the patient fails to breathe spontaneously during the cycle, or if a preset apnoea interval is identified, the machine will initiate a mandatory breath. Depending on the patient's spontaneous breathing activity, ventilation may be performed with consistent pressure support, or only mandatory ventilation is applied.

Currently, two manufacturers offer two similar concepts:
Automode: volume-controlled : volume support
Dual VC-SIMV ST : (VCV : dynamic PSV)
Automode: pressure-controlled ventilation : pressure support
BiLevel ST: (Bilevel : PSV)
Automode: PRVC : volume support
Dual BiLevel ST: (dynamic Bilevel : dynamic PSV)

Occlusion Pressure Measurement: P.01



The occlusion pressure P0.1 is a measure of the central ventilatory drive in spontaneously breathing patients. Values from approx. 1.5 to 4.5 mbar are considered the normal range. Values below 1.5 mbar indicate low ventilatory drive, e.g. due to excessive sedation or overly high pressure support settings. Values above 4.5 mbar are a sign of increased ventilatory drive. In those cases, it is recommended to adjust the sedation or increase the pressure support. When used in spontaneously breathing patients, P.01 measurements provide a measure of the negative pressure difference (P2 - P1) generated against an occlusion in the first 0.1 seconds.

Expressed as an absolute value:

1–4.5 mbar: normal value

6 mbar: risk of respiratory muscle fatigue due to excessive effort required (weaning failure)

Expressed as a relative value:

Increase by > 4 mbar during spontaneous breathing:
risk of respiratory muscle fatigue

Rapid Shallow Breathing Index: RSBI

$$\frac{\text{respiratory rate /min}}{\text{tidal volume (L)}}$$

The rapid shallow breathing index (RSBI) is a weaning indicator that can be a tool to predict successful outcomes. The RSBI is calculated by dividing the patient's spontaneous respiratory rate per minute by the measured tidal volume (in litres).

Examples:

$f = 25$ $VT = 0.25 \rightarrow RSBI = 100$

$f = 30$ $VT = 0.35 \rightarrow RSBI = 85.7$

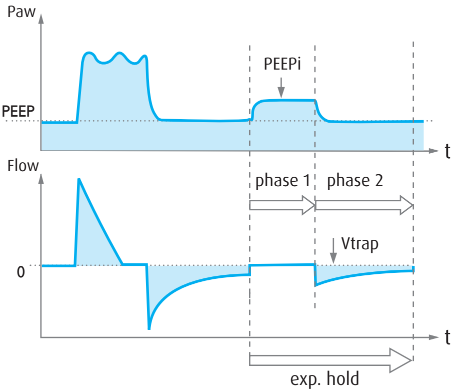
$f = 30$ $VT = 0.25 \rightarrow RSBI = 120$

The higher the RSBI in a spontaneously breathing patient, the less likely it is that weaning will be successful:

RSBI < 100 : weaning likely to be successful

RSBI > 105 : weaning unlikely to be successful

PEEPi: Intrinsic PEEP

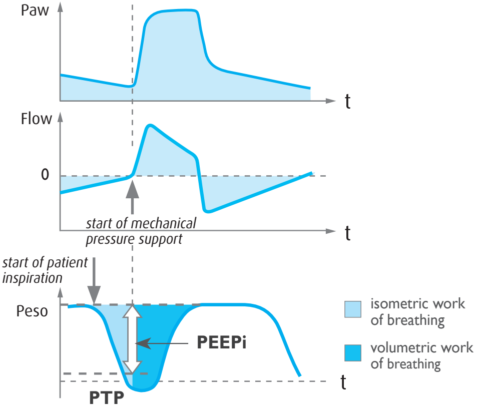


Irrespective of the adjustable PEEP level, a functional PEEP may be effective, which is generated by incomplete expiration.
A multi-step PEEPi measurement during a prolonged expiratory phase allows for measuring the functional PEEP, which is frequently referred to as auto-PEEP, to determine the trapping volume. **This manoeuvre only provides reliable results with controlled ventilation (passive patient).**

Expressed as an absolute value:
- determination of the intrinsic PEEP and the trapped volume
- information about the overall PEEP

Expressed as a relative value:
- effect on PEEP and trapped volume when respiratory rate, inspiratory time, or I:E ratio is adapted

Intrinsic PEEP measurement in spontaneously breathing patients



In contrast to PEEPi measurements in a prolonged expiratory hold manoeuvre, the intrinsic PEEP can also be continuously recorded in a spontaneously breathing patient with a properly placed oesophageal pressure measurement catheter. For example, this enables PEEP adjustment for the purpose of minimizing intrinsic PEEP.

This involves measuring the drop in oesophageal pressure that is not affecting the flow at the start of inspiration. It is considered a surrogate parameter for functional PEEP and can also be used to calculate the trapped volume.

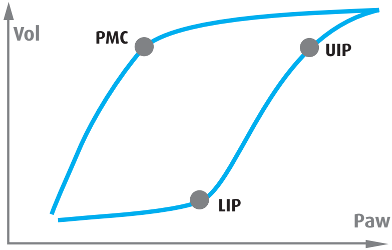
Expressed as an absolute value:

- determination of intrinsic PEEP
- information about the overall PEEP

Expressed as a relative value:

- effect on PEEP when respiratory rate, inspiratory time, or I:E ratio is adapted

Inflection Points: LIP / UIP / PMC



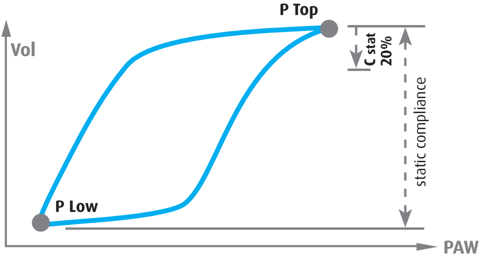
A manoeuvre can be performed to obtain a representation of the respiratory mechanics of the lung in the form of a pressure-volume curve. The following inflection points can be established in most cases:

LIP: Lower Inflection Point	Start of maximum slope in an inspiratory pressure-volume curve (compliance is highest from this pressure)
UIP: Upper Inflection Point	End of maximum slope in an inspiratory pressure-volume curve (compliance decreases from this pressure)
PMC: Point of maximum curvature	Point of maximum curvature of the expiratory pressure-volume curve (if this pressure is set as PEEP, the achieved lung recruitment can generally be largely maintained)

Possible applications:

Setting PEEP based on lower inflection point LIP	**LIP** = necessary PEEP = LIP +2 mbar
Limitation of the plateau pressure or maximum inspiratory pressure based on UIP	**UIP** = maximum plateau pressure or maximum inspiratory pressure
Setting PEEP based on point of maximum curvature: PMC	**PMC** = PEEP

C20/C Index



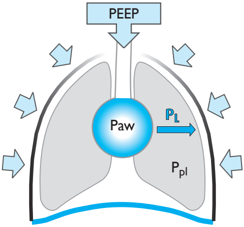
The C20/C index is calculated based on the individual measurements of the PEEPfinder.

This "overdistension index" is calculated in inspiration and results from the ratio of the compliance calculated from the last 20% of static compliance to the measured compliance between P Low and P Top.
An index below 0.8 may be indicative of an overdistended lung.

TPP exp: end-expiratory transpulmonary pressure
TPP insp: end-inspiratory transpulmonary pressure

To prevent alveolar collapse, positive transpulmonary pressure (the difference between alveolar pressure and pleural pressure) is required.
As a surrogate parameter for pleural pressure, the oesophageal pressure can be measured with a modified gastric probe (PESO balloon catheter) for calculating the transpulmonary pressure.

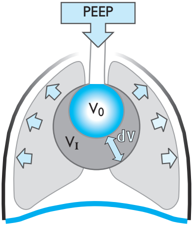
The end-expiratory transpulmonary pressure **TPP exp** (the difference between end-expiratory alveolar pressure and pleural pressure) can be influenced by titrating the applied PEEP.
A PEEP setting resulting in an end-expiratory transpulmonary pressure in the positive range (e.g., between 0 and 10 cmH_2O) can help to decrease cyclical alveolar collapse.



TPP_{exp} = PEEP - Pes

TPP_{exp} ≈ alveolar collapse

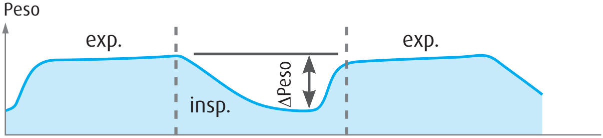
The end-inspiratory transpulmonary pressure **TPP insp** (plateau pressure – pleural pressure) reflects the lung distension at the end of inspiration. As a general rule, TPP insp should be kept below 20 cmH_2O.
The pressure difference between end-inspiratory and end-expiratory transpulmonary pressure (transpulmonary driving pressure = TPP insp - TPP exp) should remain below 12 cmH_2O if possible.



TPP_{insp} = Plateau - Pes

TPP_{insp} ≈ distension

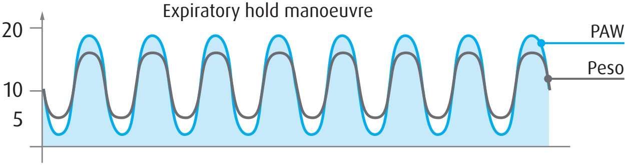
ΔPeso: Oesophageal pressure amplitude



Inadequate relief of the diaphragm musculature in spontaneously breathing patients can cause ventilator-induced diaphragmatic myotrauma. The amplitude of the oesophageal pressure (ΔPeso) serves as a bedside indicator for an increased respiratory muscle effort in spontaneously breathing patients.

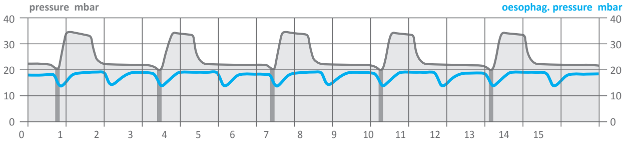
ΔPeso guidance values:
4 – 8 mbar: Standard values > 12 mbar: inadequate spontaneous breathing

ΔPes/ΔPaw (Baydur test)



In spontaneously breathing patients, the recommended test to validate the Peso measurement consists of comparing the simultaneous, negative deflections in the airway and oesophageal pressure curves during an end-expiratory occlusion manoeuvre (so-called Baydur test).
During the occluded inspiration, pressure changes in the airways (ΔPaw) and the oesophagus (ΔPes) should be almost identical because he lung volume does not change. Peso measurements can be considered reliable if the ΔPes/ΔPaw ratio is between 0.8 and 1.2. Otherwise, the catheter should be repositioned and/or the balloon volume checked again.

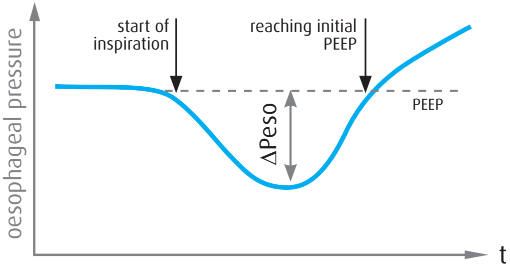
Detecting patient-ventilator asynchrony



Patient-ventilator asynchrony can be detected based on the correlation between the airway pressure curve to the oesophageal pressure curve:

Asynchrony:	No negative Peso before ventilator delivers pressure in spontaneously breathing patients
Auto trigger:	No negative Peso before ventilator delivers pressure in spontaneously breathing patients
Ventilator-induced asynchrony (delayed cycling):	Peso inspiratory time shorter than inspiratory phase of ventilator
Reverse triggering:	Periodic negative Peso after delivering mandatory breaths

PTP: Pressure Time Product



Measuring the oesophageal pressure allows for quantifying the respiratory efforts of a spontaneously breathing patient to individually adjust the level of relief for the work of breathing. This enables the detection of increased respiratory muscle effort, which is associated with possible respiratory fatigue, and can therefore minimize the risk of weaning failure. The inspiratory work of breathing can be calculated as an area integral over time (PTP = pressure time product). The pressure time product is considered an effective method for assessing energy consumption (force x displacement) of the respiratory muscles. In a spontaneously breathing patient, the work of breathing performed by the respiratory muscles equals the integral of the product of P_{mus} and the volume change.
There is typically a close correlation between WOB and PTP.

Guidance value from the literature:
< 150 cm - H_2O*s

Expiratory time constant: RCexp

$$\frac{0.75 \times VT}{\text{flow in ml/s}}$$

Aside from an evaluation of both pressure-flow curve and PEEPi measurements, the expiratory time constant (RCexp) also provides a method of detecting air-trapping (Auto-PEEP). Another option is to calculate the total expiratory time required. This involves calculating the ratio between the expiratory tidal volume and the expiratory flow rate, and expiratory time.

RCexp provides information on end-expiratory volume as a percentage of total lung volume:

After RCexp x 1 approx. 63% of the lung volume has been emptied
After RCexp x 2 approx. 86.5% of the lung volume has been emptied
After RCexp x 3 approx. 95% of the lung volume has been emptied
After RCexp x 4 approx. 98% of the lung volume has been emptied

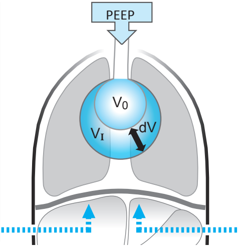
In clinical practice, the relevant I:E ratio setting is commonly estimated as follows:

RCexp x 3 = time for expiration in patients without COPD
RCexp x 4 = time for expiration in patients with COPD

Intra-abdominal pressure monitoring (IAP)

Intra-abdominal hypertension and abdominal compartment syndrome

Primary causes:
- Blunt or penetrating abdominal trauma
- Liver transplantation
- Ruptured abdominal aortic aneurysm
- Postoperative bleeding
- Retroperitoneal haemorrhage
- Mechanical intestinal obstruction
- Post-surgical intestinal occlusion
- Pelvic fractures with internal bleeding



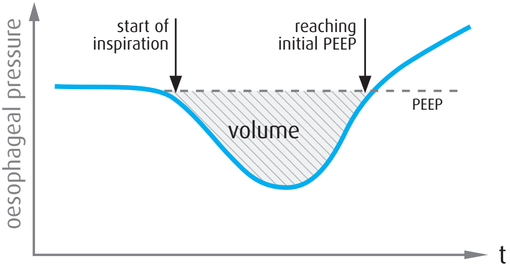
Secondary causes:
- Severe intra-abdominal infection
- Large-volume fluid replacement
- Ascites
- Pancreatitis
- Ileus
- Sepsis
- Major burns
- Continuous ambulatory peritoneal dialysis
- Morbid obesity
- Pregnancy

To diagnose intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS), the bladder pressure can be recorded as a surrogate parameter for intra-abdominal pressure (IAP). The following is considered the gold standard for intermittent IAP measurements:

- Maximum bladder instillation volume: 25 ml sterile saline solution
- End-expiratory measurement in supine position
- Exclusion of existing abdominal muscle contraction
- Artefacts such as coughing, sneezing or loud speaking can temporarily lead to a sharp increase and drop of IAP.

	Adults	Paediatrics
Standard values	approx. 5 – 7 mmHg	approx. 4 – 10 mmHg
Intra-abdominal hypertension (IAH)	Stage I: 12 – 15 mmHg Stage II: 16 – 20 mmHg Stage III: 21 – 25 mmHg Stage IV: > 25 mmHg	> 10 mmHg
Abdominal compartment syndrome (ACS)	continuous IAP > 20 mmHg	continuous IAP > 20 mmHg

WOB: Work of breathing

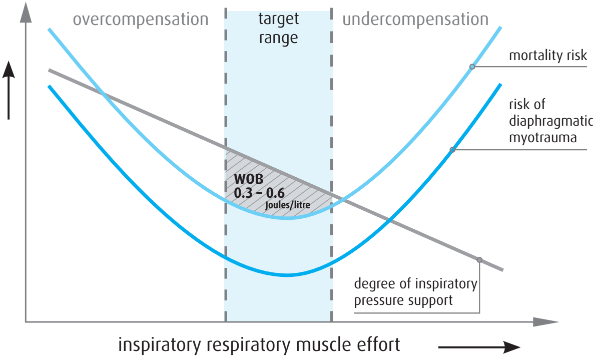


Work of Breathing (**WOB**) is the quantitative expression (∫ pressure x volume) of the energy required for respiration per unit of volume. It is measured in joules per litre (J/L). If the oesophageal pressure is measured, the patient's WOB can be calculated continuously. In spontaneously breathing patients, WOB can also be approximated without oesophageal pressure measurement and is displayed separately for the patient and the ventilator (WOBpat, WOBvent). The higher the flow and airway resistances (resistance, elastance), the higher the WOB. An excessively high WOBpat is associated with a risk of respiratory fatigue.

Published guidance values:

Adults:	0.3 – 0.6 J/litre
Children & adolescents (6 to 18 years):	0.1 – 0.6 J/litre
Infants:	0.02 – 0.2 J/litre

POB: Power of Breathing



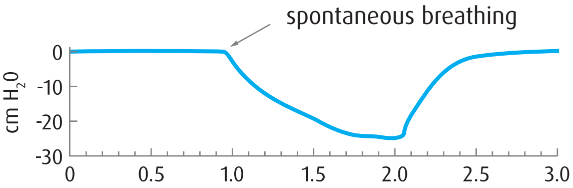
Power of breathing (POB) is the quantitative expression (∫ pressure x volume) of the energy required for respiration per unit of time. It is measured in joules per minute (J/min). It can be calculated by multiplying WOB (see section above) with the respiratory minute volume (RMV)

POB (J/min) = WOB (J/l) x RMV (l/min).

An overly high POB is associated with a risk of respiratory fatigue and potential lung injury. A value of approx. 12 – 15 J/min is considered the "critical threshold" for lung injury.

Image source: Oczenski, W.; Hörmann, C. (2020): Mythos der Spontanatmung beim ARDS – zwischen Muskelrelaxierung und Zwerchfellprotektion, in: Böttiger, B.; Kuckelt, W.: Jahrbuch Intensivmedizin 2020, Lengerich, Pabst Publishers, S. 192

Maximum Inspiratory Pressure: MIP



Another weaning indicator is the MIP (maximum inspiratory pressure) manoeuvre, which provides information on the patient's current maximum peripheral respiratory muscle strength. This is also often referred to as the negative inspiratory force (NIF) index.

MIP measures the maximum inspiration effort produced after a prolonged expiratory phase (expiratory hold manoeuvre) and against an occlusion. Despite being considered controversial, this indicator value is used in clinical practice, particularly in patients with neuromuscular disorders.

< 20 mbar: weaning unlikely to be successful
> 20 mbar: weaning likely to be successful

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Despite the authors' meticulous research, the reader retains full responsibility to ensure that any information used as part of the clinical decision-making process is verified by cross-referencing with the relevant clinical information and the manufacturers' current instructions for use.

Editors:
Peter Kremeier, Christian Woll
Understanding and comparing modes of ventilation –
The Kronberg List of Ventilation Modes
5th Edn.

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In the absence of regulatory requirements, ventilator manufacturers have independently defined a wide range of terms and abbreviations for the ventilation modes they use. For reasons of competition and marketing, the names of such modes are frequently subject to trademark protection. As a result, the current nomenclature for ventilation modes is characterised by inconsistent and manufacturer-specific designations. This is not only confusing for users in clinical practice, but also for readers of textbooks and articles.

Over the years, there have been a number of voluntary initiatives to standardise the ventilation taxonomy. Robert L. Chatburn published the first classification scheme for ventilation modes in 1992, followed by updated versions in 2007 and 2014, respectively, as taxonomies for ventilation modes. Unfortunately, these terms did not become established in practice and were mostly ignored by medical device manufacturers. Solutions for a uniform nomenclature for ventilation and a standardized classification system for ventilation modes have also been pursued on a European level. A uniform nomenclature was published for the first time in the second half of 2019, in the form of the international standard ISO 19223:2019. The published standard has been an important step on the way to manufacturer-independent naming of ventilation modes to reduce potential user errors and improve comparability.

We hope that the Kronberg List will go some way towards guiding you through the labyrinth of ventilation modes, and that it proves useful as a quick reference guide in bedside decision-making. Comparison tables that acknowledge differences between different manufacturers' devices, and which provide detailed descriptions of all relevant characteristics, will make it easy for the user to compare the relevant ventilation methods. Due to the increasing relevance of outpatient ventilation devices, so-called homecare ventilation devices were included as well. Schematic explanations of different nomenclatures were included to facilitate studying the international professional literature. The new edition has been completely revised and expanded.

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